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ANNUAL PROGRESS REPORT

Nov 1961 - Jan 1962

Norman K. Walker and Charles J. Fricker

Institute for Behavioral Research

The Use of Tracking Tasks as Indicators of Stress

This study was supported by U.S. Army Medical Research  
and Development Command under Research Contract No. DA-49-193-MD-2208

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## INTRODUCTION

This is the first progress report on a pilot study to determine whether certain tracking tasks can be used as accurate indicators of the stresses on human beings. Tracking tasks have been used before for this purpose by many investigators, especially by Garvey and Henson of the U. S. Naval Research Lab. However, in all previous experiments it was apparently considered that the errors would not be appreciable unless the operator were asked to track a moving target. The present investigator has had a great deal of experience in various human operator guided missile systems in which the target is substantially fixed and has found that under these conditions and with the usual control systems the response of the human being is oscillatory and that the amplitude of the oscillations is determined largely by the character of the control system and does not vary very greatly from operator to operator.

A detailed experiment to confirm previous unpublished results was made as part of a study by Walker at the Johns Hopkins University Applied Physics Laboratory with the results as shown in Figure 1.

The simplest possible control system to use for experiments of this type is the acceleration system in which the movement of a control stick by the operator is integrated twice to produce acceleration of the display spot and under these circumstances there is a unique relation as shown in Figure 1 between the angular acceleration which the operator can apply to the spot and the average error observed. This tends to be a constant ratio as long as the errors are easily seen but when the errors become comparable to the limit of vision ( $|\bar{e}| \approx 0.2$  mils) they tend to

become constant irrespective of the stiffness of the system.

The constant ratio implies that there is a constant lag in the system which can only be due to the human operator himself, and must represent the summation of a whole series of lags one of which may be described perhaps as a "thinking time".

The system can be made more difficult by causing the operator to think more carefully what his response should be and the APL tests showed that if one additional integrator were inserted in the system it became almost impossible to control. If, on the other hand, one integrator were removed from the system, giving "velocity" control then the system was so easy to control that the errors were inappreciable. Graduations between one, two, and three integrator systems can be derived by adding lag to the system (about 3 seconds lag is equivalent to adding an integrator) or by adding lead or phase advance (a lead of about 3 seconds roughly cancels the effect of an integrator).

Hence the use of an acceleration or two-integrator system coupled with appropriate lead and lag networks covers the entire range of human response from ridiculously easy to extremely difficult and it has been found that for most subjects any one system will give consistent results.

By using equipment of this type with a direct read out of error it is hoped to provide an accurate and effective "man-meter" which can be used to investigate changes in the operator's performance under stress and hence to calibrate and compare the stresses themselves.

## EQUIPMENT

A block diagram of the equipment is shown in Figure 2.

The human operator observes a display and can control the left and right motions of a spot of light by left and right motions of a control stick. The output from the stick is fed to an analog computer consisting of two Philbrick K2W amplifiers in cascade, the necessary stabilizing amplifiers and associated lead and lag networks giving an output which is basically the double integral of the input and thus producing an acceleration response of the display spot. The equipment has switches by which lead or lag can be added to the output and it is also possible to bypass one of the integrators.

A fruitful source of error in previous experiments which have usually used a display oscilloscope and a separate pen recorder has been differential zero error and drift between the display and recorder. In our equipment these sources of error are eliminated by the use of a Minneapolis Honeywell Visicorder 1406 in which the same spot of light serves as the display and also forms the record trace. It is convenient that the small time delay which is inherent in this form of recorder prevents the subject from observing his previous results which the APL tests showed could have a large effect on the errors. Three other channels of the recorder are used to indicate time markers, control stick movements and the integrated mean error. Hence all information necessary to analyze the experimental data is produced at one time on the same record.

No errors can arise due to drift in the control stick display loop since the operator is continuing to restore this to the null position. However, in the direct read out of error, drift can occur. We therefore

take the output from the computer which forms the display, rectify it and integrate once. The slope of this display or the displacement after a fixed time interval is a measure of the mean modular error ( $\bar{e}$ ) and this has been selected in preference to the RMS error as a final output since any zero error or linear drift which is within the bounds of the oscillatory display is thereby eliminated. A further channel is provided to give a record of the stress on the subject and three other channels are available to record physiological data if desired.

As presently constructed the equipment is portable but is hardly miniaturized and the intention is, should the program be extended, to develop small portable equipment for field tests with similar properties.

#### EXPERIMENTAL TECHNIQUE

The subject is given a short indoctrination on the properties of the system and is allowed to commence the experiment with the stick control in the tri-stable position. That is to say, he can issue commands for left or right acceleration and also has the option of leaving the stick central with no output which is an aid in training. Once tracking has been established, however, it has been found best to eliminate the center position of the stick which now becomes bi-stable and forces the operator to track continuously since it is possible for a very alert or very highly skilled operator to use a quantized technique with the tri-stable system which gives much more accurate but less useful results. The operator tracks for at least one minute, (and we now believe the time interval should be increased) and the observer notes the progress of the integrated mean error and resets this as

necessary to avoid interference with the display. At the end of the run the operator is asked to check the calibration of the Integrator by tracking known fixed displacements and to check the stick output by giving full deflection left and right for at least 2 seconds. A typical pace is shown in Figure 9.

#### PRELIMINARY RESULTS

A series of preliminary experiments have been made into interesting stress conditions during the course of development of the equipment. These were not made under closely controlled conditions but were intended to provide some experience which could be used to determine how the future experiments should be run and to investigate the performance of the equipment.

##### The Effects of Alcohol -

Four subjects A, B, C and D with associated operating staff were assembled in the lab and each was given an indoctrination training run on the equipment. Each was then given a run of one minute duration with 2 Integrators and no lag followed by a one minute run with 2 Integrators and 1.6 seconds lag. The results showed this latter task was too difficult and they have not been reproduced. Following the runs each subject was administered alcohol in the palatable form of one standard measure of a proprietary brand of Manhattan cocktail and the experiment was then continued. It was found that a complete rotation of tasks took 20 minutes so the results as shown in Figures 3, 4, 5 and 6 are the results obtained for each subject with a 2 Integrator tracking task at 20 minute intervals while imbibing alcohol at the rate of one Manhattan every 20 minutes. Operator A, the first author, showed some slight improvement

for the first four tests followed by a slight degradation, the experiment being discontinued after the 7th test run when supplies of recording paper and alcohol ran out simultaneously.\* Similar results were obtained with Operator B and with Operator C, but it is interesting to note that Operator C on the final test showed a sudden large degradation in performance. Operator D represents an interesting case. He had some difficulty in learning to track with the equipment as excessive errors necessitating a reset developed on two occasions during the training run and his average errors during training were much greater than those for the other subjects. However, the affect of alcohol in each case was to cause a steady improvement in performance throughout the experiment.

An interesting side result was observed when some of the assistants also took training runs. It was noticeable that the training run for Mrs. C. Figure 7b was notably more accurate than for her husband and she learned to operate the equipment to the limiting accuracy within 15 seconds as compared to the 30-60 seconds which is normal for the other operators. This agrees with previous reports from guided missile investigations that young women are better operators in this type of tracking task than men.

#### (4.2) The Effect of Lag in the Display

On the following morning the writer, Operator A, attempted to repeat the runs both with 2 integrators and with 2 integrators and 1.6 sec lag for extended periods of time. Figure 7a shows that he now had no difficulty in holding an acceptable accuracy for several minutes in either case but that, as would be expected, the maximum errors with the lag are roughly trebled. On this occasion, which still represented an

\* The Total Amount Consumed Was 3/4 pint/Operator, 80° Proof

early stage in the development of the equipment, the errors were rectified and then smoothed with a large time constant. This display was also reproduced in Figure 7b but it is evident that this is not a sufficiently good indicator of the average errors.

#### (4-3) The Effect of Fatigue

After the new error integrating equipment had been built it was used to investigate the effect of fatigue. Operator A tracked continuously for a period of almost one hour starting at 10:40 at night and the results are reproduced in Figure 8. These show firstly, that the new method of scoring error is extremely effective since it detects a slow and steady degradation of performance which is probably not evidenced from the direct record. A much more interesting result, however, was obtained half way through the run when it was decided to check the calibration of the integrator by moving the tracking points one inch to one side for one minute. Apparently the additional interest this brought to the task coupled with the knowledge that it was of short duration only, resulted in greatly improved performance and on resumption of the original tracking task some measure of improvement was maintained. Towards the end of the run the operator became apparently very fatigued but could still perform quite creditably. However, in the final minute or two approaching the deadline, some improvement became apparent, which was lost when it was agreed to make one more run (Run E). The calibration runs were repeated again and once more a great improvement in accuracy is evident.

#### (4.4) The Effect of Sleep Deprivation

A further experiment was made early one morning on Operator D

who had been without sleep on continuous duty for 24 hours. These results have not been reproduced as they are still being analyzed but they show some degradation in performance and in addition a tendency toward a doubling of lags during the course of the experiment. These periodical regions of increased error are then followed by short periods of sleep and it is noticeable in some of the runs that the operator continues to oscillate the stick in a mechanical manner although the indicator is drifting steadily off to one side, implying that he is now asleep in that he is not recognizing the accumulation of error.

(5) FUTURE WORK

The results to date are considered to be very promising. The equipment is simple to use and the read out of error is convenient and is apparently capable of detecting quite small changes in performance. We propose to repeat all the experiments described for a number of subjects under controlled conditions and will also investigate the effects of oxygen starvation and of vertigo.

(6) ACKNOWLEDGMENTS

The authors, on behalf of the Institute for Behavioral Research, wish to thank Major H. Williams, Dept. of Experimental Psychology, U.S. Army Walter Reed Institute for the provision of some items of the equipment, and for his encouragement and assistance.

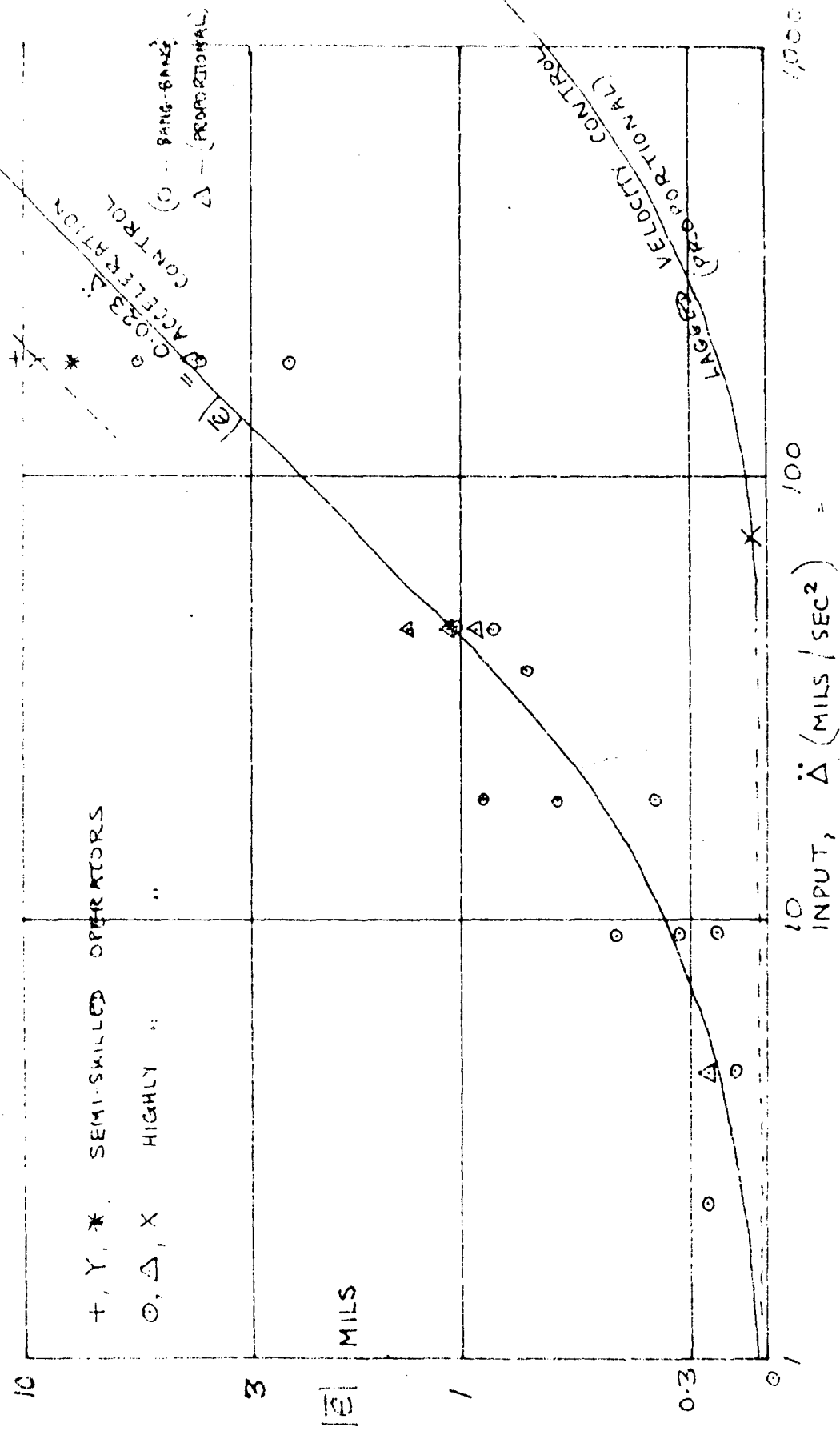


FIG 1 RESULTS OF APL/JHU TESTS ON SIMPLE SYSTEMS (N.K. WALKER)

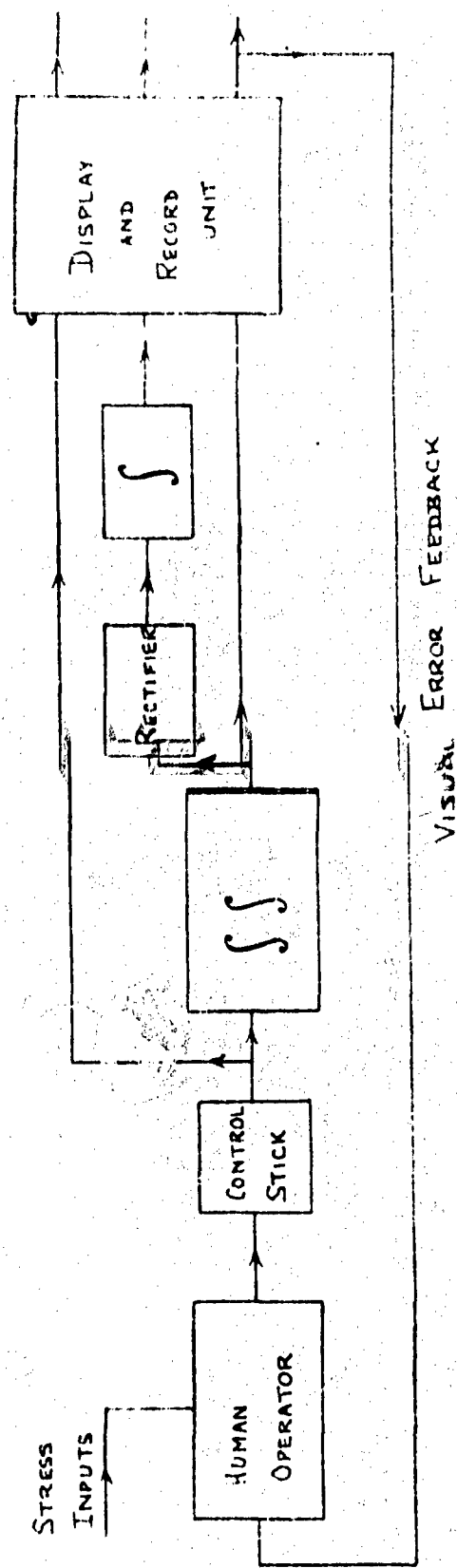
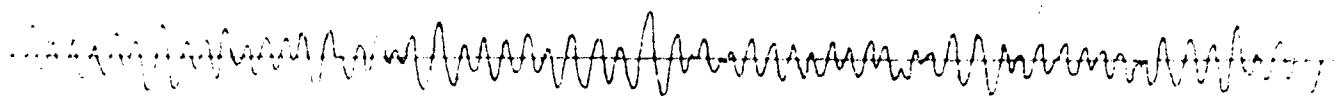
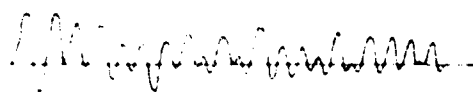


FIG 2 BLOCK DIAGRAM FOR ZERO INPUT TRACKING ANALYSIS

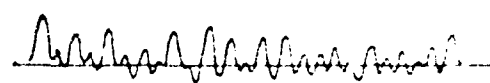


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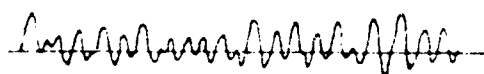
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11 46 a.m.



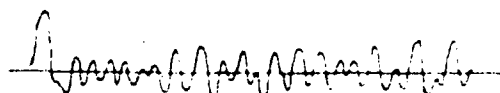
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12 07 p.m.



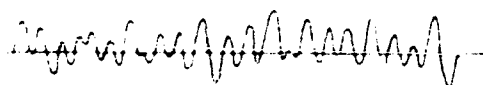
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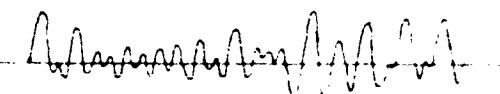
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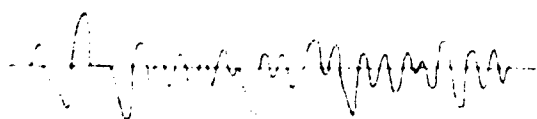
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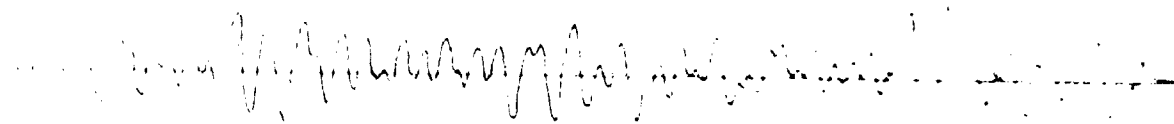
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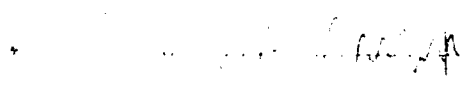
FIG. 3 OPERATOR A.  
(EFFECT OF ALCOHOL)



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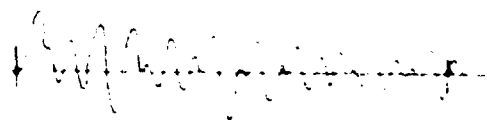
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12:15pm



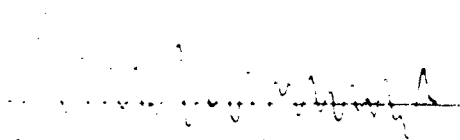
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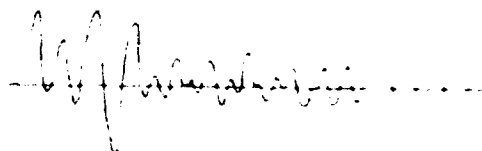
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12:17pm



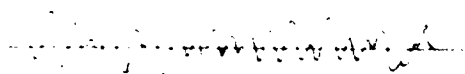
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12:37pm



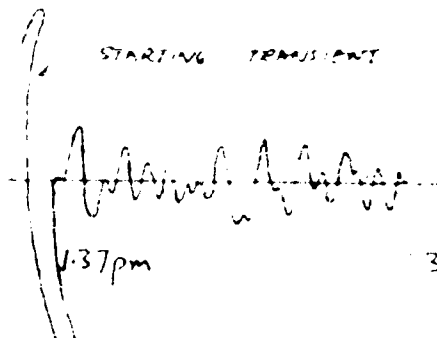
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12:58pm



1:15pm

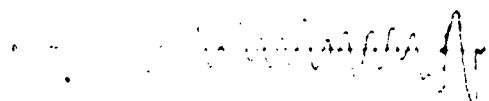
1:15pm



STARTING TRANSIENT

1:37pm

1:37pm



1:54pm

1:54pm

FIG. 4 OPERATOR B

(EFFECT OF ALCOHOL)

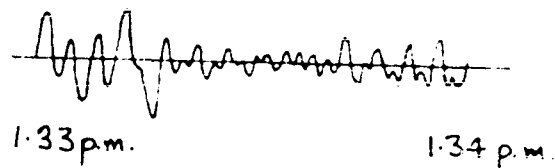
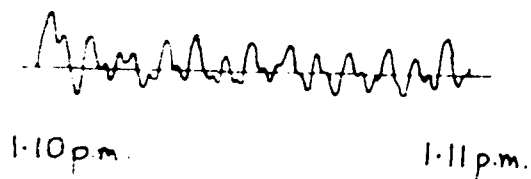
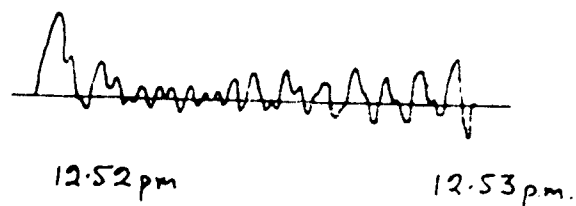
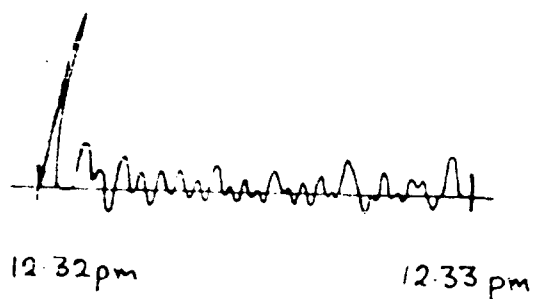
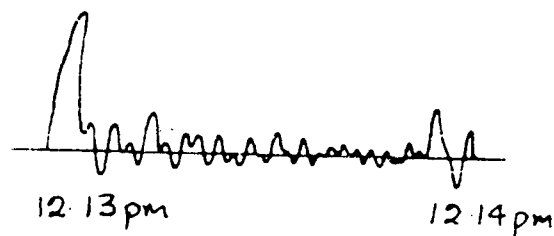
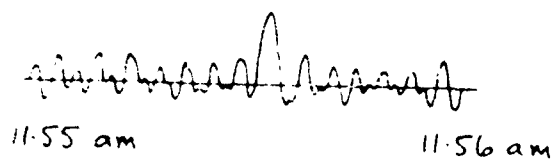
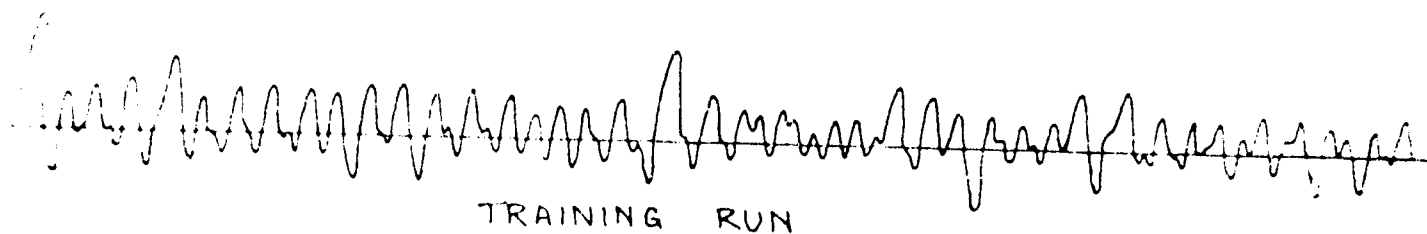


FIG 5 OPERATOR C.  
(EFFECT OF ALCOHOL)

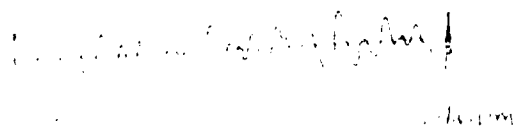
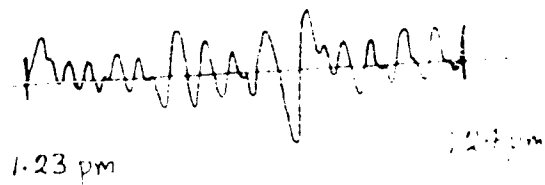
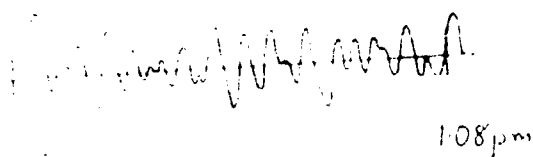
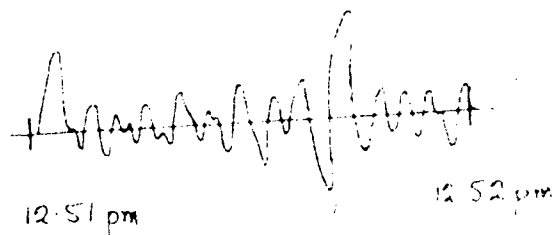
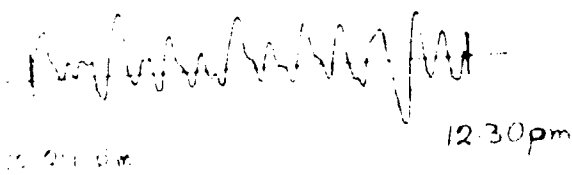
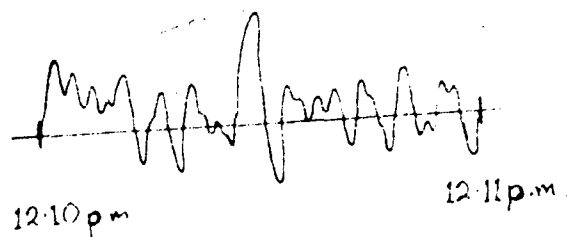
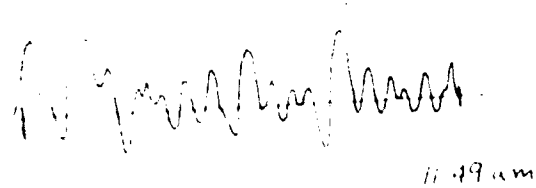
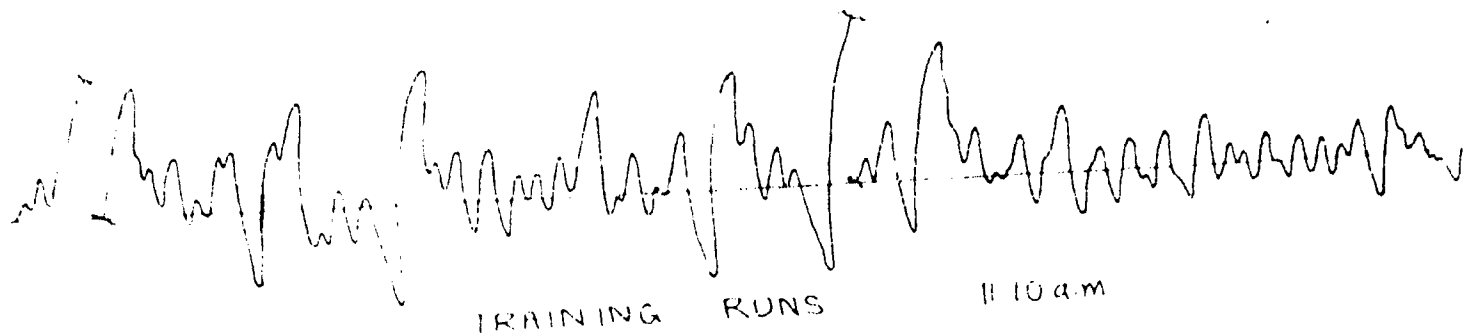


FIG. 6 OPERATOR 10  
(EFFECT OF ACCURACY)

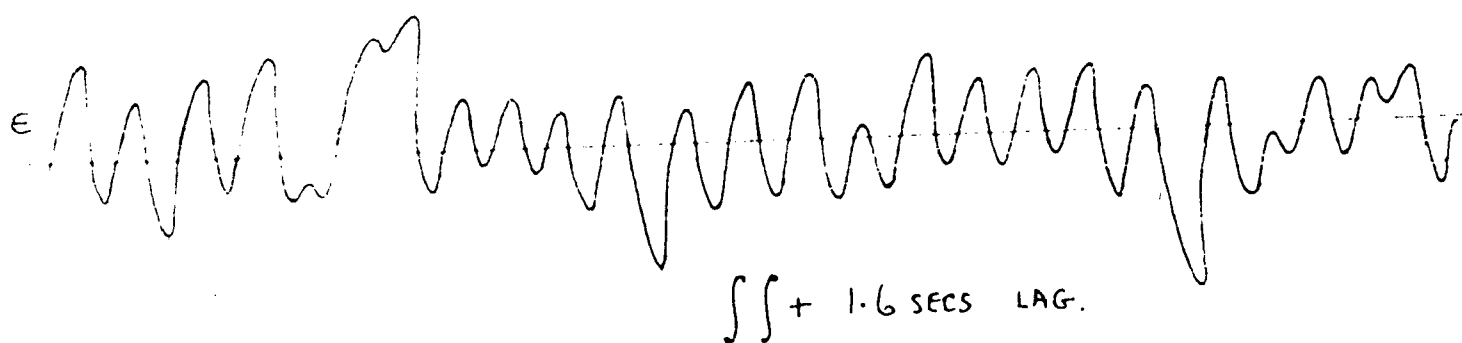
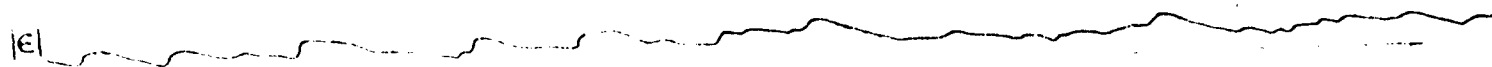
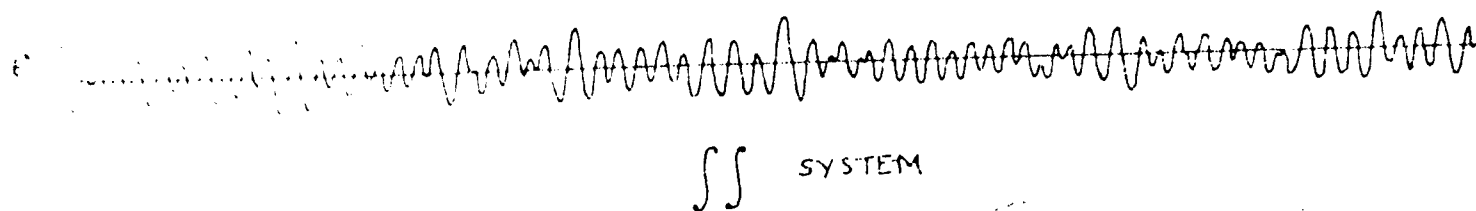


FIG 7a.

OPERATOR 'A' LATER REPEAT RUNS.

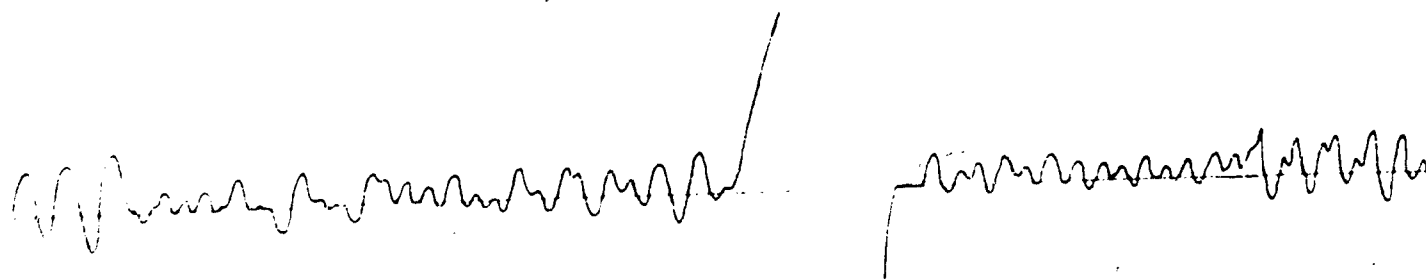


FIG 7b. TRAINING RUNS, MRS C.

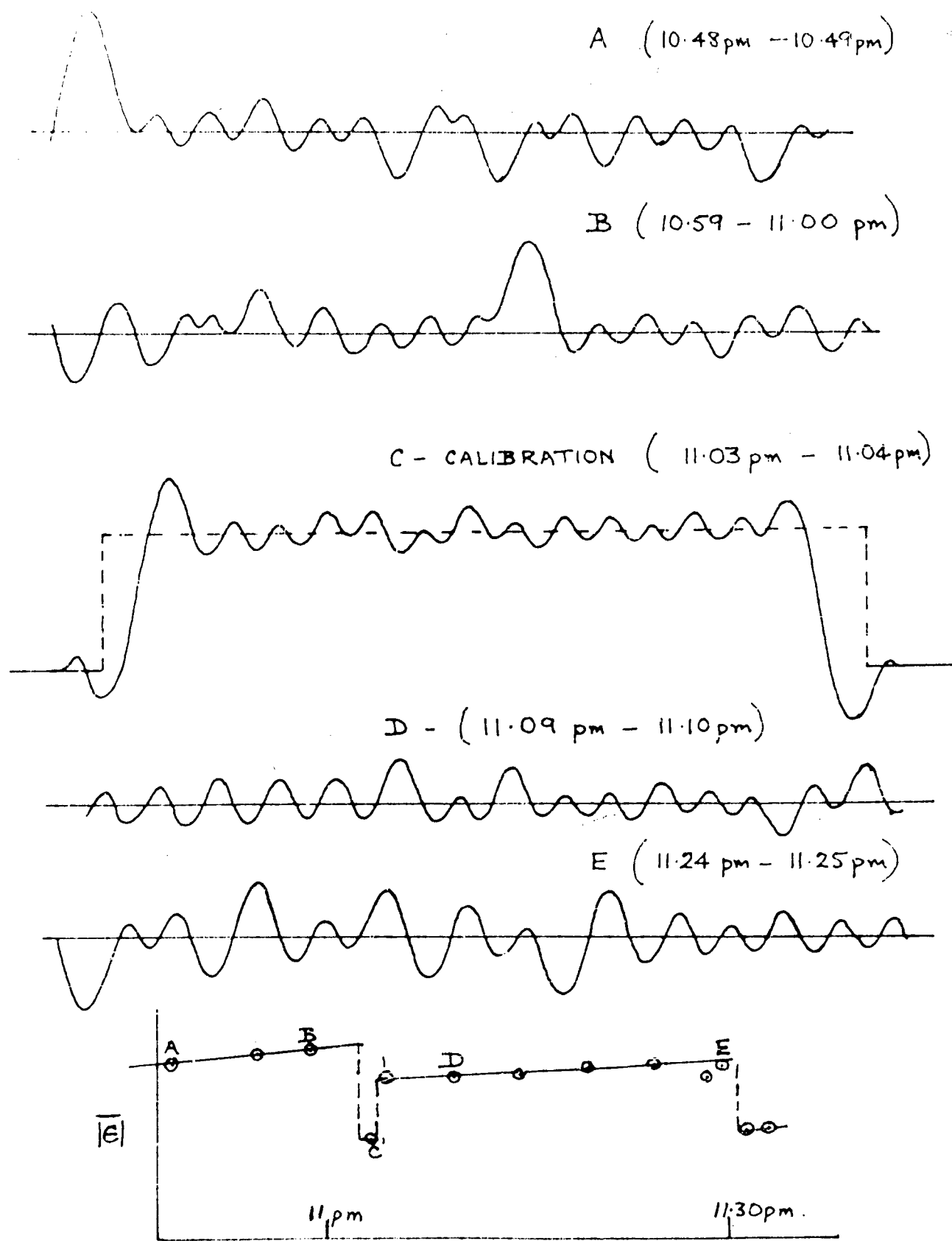


FIG. 8 EFFECT OF FATIGUE ON TRACKING ACCURACY (h)

(OPERATOR A)

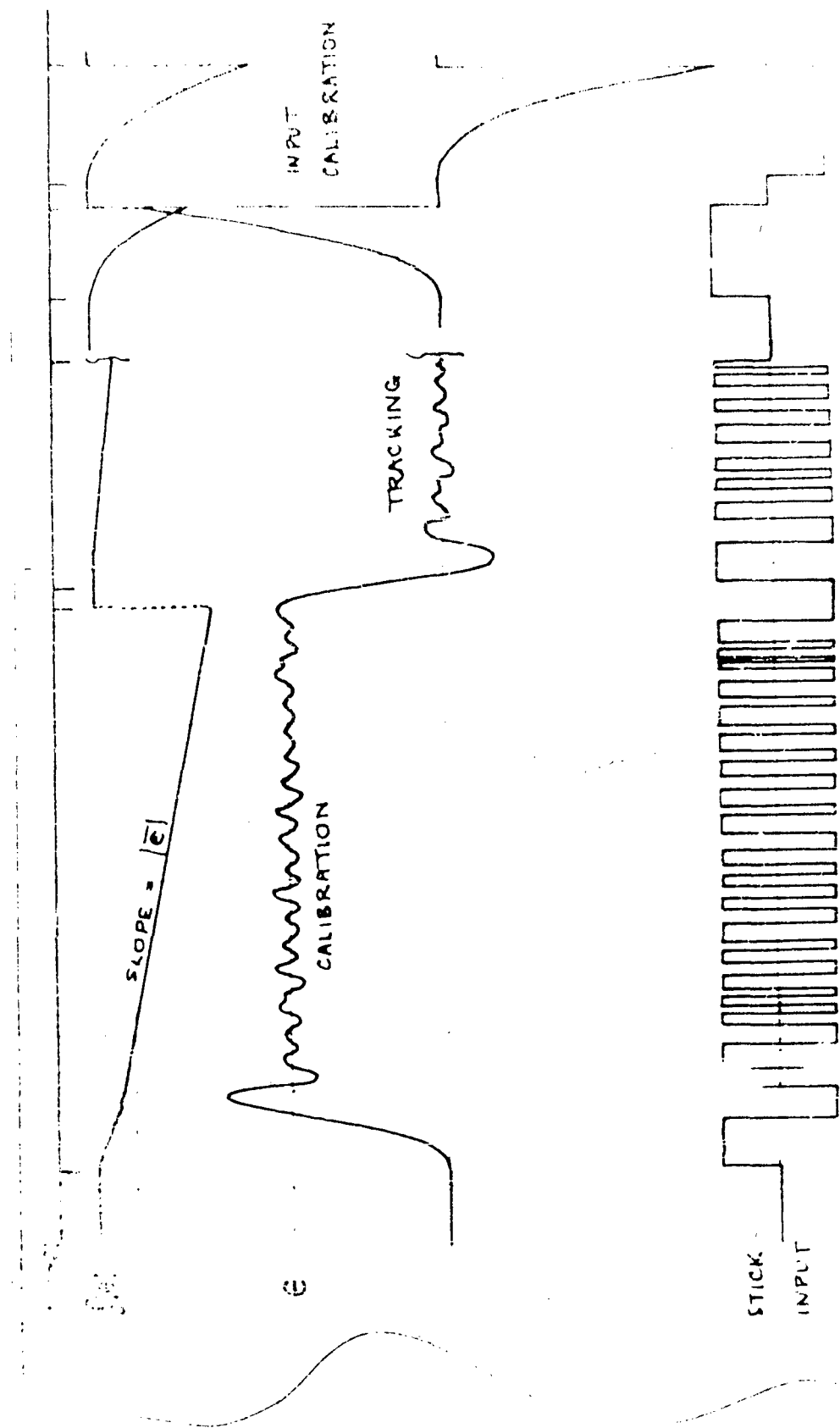


FIG 9 TYPICAL ZTTA. 1 RECORD

## ABSTRACT

1. Preparing Institution: Institute for Behavioral Research
2. Title of Report: The Use of Tracking Tasks as Indicators of Stress.
3. Principal Investigators: Norman K. Walker and Charles J. Fricker
4. Number of pages, illustrations and date: 9 pages, 9 illustrations,  
November 1961 - January 1962
5. Contract Number: DA-49-193-MD-2208
6. Supported by: U. S. Army Medical Research and Development Command  
Department of the Army, Washington 25, D. C.

This is the first progress report on a pilot study to determine whether certain tracking tasks can be used as accurate indicators of the stresses on human beings.

It has been found that if a human operator is asked to return an indicator to a fixed position by moving a control stick, the indicator deflection being, for instance, the second integral of the control stick displacement, then the response is a continuous oscillation about the null position. The error can only be due to the man himself, and under suitable conditions will be in fixed ratio to the stick input.

It is known that stress will cause degradation of operator performance so stresses can be directly compared numerically by comparing error ratios.

Analog computation equipment has been assembled which gives a direct readout of the mean modular error, and great care has been taken to eliminate drift and zero errors.

Preliminary experiments are described which show the effects of alcohol, of long continuous runs and of fatigue. Results show that the equipment is effective and simple to use, that most persons have similar errors, that abnormal people are easily detected, and that the stresses listed do cause noticeable changes in performance.

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